Chapter 9
Progressive Adaptation: The Key to Sustaining a Growing Global Population

9.1 Adaptation

Adaptation is an evolving long-term process during which a population of life forms adjusts to changes in its habitat and surrounding environments. Adaptation by the global community as a unit is vital to cope with the effects of increasing populations, global warming/climate change, the chemical, biological, and physical impacts on life-sustaining ecosystems, and competition for life sustaining and economically important natural resources. The latter include water, food, energy, metal ores, industrial minerals, and wood. Within this framework, it is necessary to adapt as well to changes in local and regional physical conditions brought on by natural and anthropogenic hazards, by health threats of epidemic or pandemic reach, by social conditions such as conflicts driven by religious and ethnic fanaticism, and by tribalism and clan ties.

9.2 Adaptation to Population Changes

Although the rate of global population growth is declining and is expected to fall to the replacement level by mid-twenty-first century, it is still increasing by about 75–80 million people annually (see Chap. 1). A grand part of the growth is taking place in Africa, Asia, Latin America, and the Middle East that together already accounts for a 2014 population of 5.9 billion of the 7.2 billion people worldwide. Conversely, populations are contracting or stable in most of Western and Eastern Europe, and Japan. Together with the United States that has a stable population, this latter group today is home to the other 1.3 billion people. Thus, although there are two population situations to adapt to, both have common problems of sustainability to address.

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The principal problems with growing populations do not involve space although population density is a problem unto itself for reasons discussed in previous chapters. The main problems are how to nourish people with food and water. The chronic malnutrition that about 1 billion people suffered from in 2013 is likely to grow in number in some regions due to global warming/climate change because humans cannot adapt to less food if they are already at subsistence rations. For example, the 2012 population in sub-Saharan Africa is 902 million people. The population is projected to increase to about 1.25 billion in 2030, an increase of about 38 %. Within the same time frame, the United Nations estimates that acreage under maize cultivation in the region will decline by 40 % because of heat and drought brought on by climate change. The loss of arable land for food production can be countered in sub-Saharan Africa if marker assisted hybridization of maize or maize genetically modified to withstand heat and drought come onto the seed market together with modified seeds for other food staples and if African nations that do not now accept GMO seeds do so in the future. If not, nations favored for food production by climate change will have a moral obligation to provide food staples to people in nations with declining food production at accessible costs based on their economies. It is clear that what happens in sub-Saharan Africa and other regions with declining cultivation acreage or that will bear other effects of climate change (e.g., drought, shifting rain patterns) will affect the rest of the worldwide community politically, economically, and socially. The earth's problems that associate with global warming/climate change will be further discussed in the last section of this chapter.

Water is the staff of life. It keeps the body hydrated and is necessary to grow food crops, hydrate food animals, and grow feed grains. Chemically or biologically polluted water does not serve these ends. If ingested, contaminated water can result in sickness as discussed in Chap. 2. Water stokes industry and manufacturing as well, thus keeping economies in many countries contributing to a population's well-being by providing employment, goods, and services. Ideally, these businesses contribute their fair share to a tax base that supports social needs (e.g., education, healthcare, maintenance of infrastructure). Factory owners adapt and plan against water shortages by having a water recycling system in place but may also slow or stop production until operational water conditions return. Citizens with a reliable water supply can adapt to periods of water shortage by limiting use according to mandates by government officials but still have water for basic daily needs. However, persons in nations with a chronic per capita water shortage may not have this option to serve their daily needs unless water is imported or new water sources are found (see Chap. 2). If imported water is not an option to meet immediate essential needs, an alternative adaptation for people (and animals) is to try to reach a location where water would be available to them. With growing populations, per capita water availability is greatly diminished (Table 2.2), water shortages become endemic, and people are at risk of existing at subsistence levels or dying. Most at risk from the lack of a basic water ration are pregnant women, infants, young children, and old people. Water wars are a future possibility as nations battle for their peoples' survival unless political differences are set aside and projects are

supported to develop and share water sources. In a welcome effort, Jordan, Israel, and the Palestinian Authority signed a memorandum of understanding in the World Bank, December 2013, with specific aims: (1) produce millions of cubic meters of drinking water for a water-deficient region; (2) pipe 200 million cubic meters of water annually ~180 km (110 mi) from the Red Sea to the Dead Sea; (3) build a desalination plant at Aqaba that would supply water to Aqaba and Eilat; (4) the Israeli Water Utility would supply 20–30 million cubic meters of drinking water to the Palestinian Authority for the West Bank population at a reduced cost; and (5) there would be an inflow of water to slow and in the future perhaps abate and reverse the shrinking of the Dead Sea. Funding for the estimated $400 million, 5-year project will come from the World Bank, donor nations, and philanthropic groups.

As the global population increases and more people in developing and less developed nations have more disposable income, there will be a growing draw on natural resources other than water and food to service their industrial, agricultural, and manufacturing needs and wants. Competition can force economic wars among national and multinational corporations for the resources necessary to provide goods and services and thus drive up prices for resources. Industries and manufacturing units that cannot compete economically for natural resources will shut down, thus contributing to unemployment and downturns in economies because of falling domestic demand. To keep order in the increasingly interdependent world economy, accommodation for shared natural resources (or substitutes for them) at affordable prices is the adaptationnecessary. This can be mandated by the World Trade Organization backed by other practical-minded international groups.

Another adverse effect of growing populations that is a national resource that can be lost at the expense of some countries to the benefit of others is brain power. This brain power has been cultivated at excellent universities in developing countries, often times at little or no cost to students (e.g., in medicine, science, engineering, economics, the arts) who attend and graduate in increasing numbers. Where there are too many well-educated professionals but lack of employment opportunities for them in their fields of expertise, educated people have the option of relocating to another country that can nurture and use the expertise. Many adapt to the employment problem by taking up this option. This may mean moving from a developing country to a developed country or from a less developed country to a developing or developed country. Ultimately, this loss of citizens with special skills can hurt a country. To counter this brain drain or reverse it, a country can adapt by investing in its future to create programs and conditions that keep talented professionals home, or if they have emigrated, entice them to return. China and India are examples of countries that have successfully taken this tact.

When there are increases in a population because of immigration, problems can ensue between immigrants and a general population. Adaptation to diversity and the multicultural experiences it brings to a community is often not a comfortable change. The antipathy of some in a host country is based on slowness of the immigrants to learn the language and inability of host country citizens to understand what immigrants are saying among themselves. This makes citizens feel uneasy.

Some view immigrants as a threat to their own or a family member's employment or advancement. Race difference is a factor that some cannot readily adapt to as is ethnicity with its traditions and customs unfamiliar to the general public. Religion can be divisive if adherents to its beliefs engage in acts of hatred detrimental to the host country fueled by fundamentalists and zealots who interpret religious writings as giving them license to commit crimes or absolving them of the crimes. Sadly, many citizens paint an entire religious community with the taint of the relatively few evildoers. Adaptation to diversity is essential for our earth's citizenry with joint efforts by all to resolve worldwide issues (e.g., global warming/climate change) so as to become the keys to providing a sound future for coming generations. There has to be a shared attack on global threats, no matter what the language, race, ethnicity, or religious beliefs are, no matter social or economic status, no matter whether a threat affects less developed, developing, or developed countries.

9.3 Adaptation to Natural Hazards

Adaptation is a progressive process when dealing with natural hazards because as each type of natural hazard impacts global communities over time, lessons are learned from each one that give direction to the methods of adjustment. Adaptation to living where hazards can be expected to strike and where populations continue to increase is dependent on what we learn from the study of past hazards. We can use this evaluation of measured and observed data to minimize the immediate effects and aftermaths of hazards and protect citizens from injury, death, and from damage or destruction of property or infrastructure when hazards strike in the future.

9.3.1 Earthquakes

In areas prone to earthquakes, we know that earthquakes do not kill and injure people but that collapsing buildings and infrastructure do. Earthquakes are not predictable so that there is no adaptation by a timely evacuation to minimize deaths and injury. However, building structures to make them more earthquake resistant can save lives, reduce injuries, and protect property. Thus, after a high-magnitude earthquake, forensic engineering teams come to assess the damage and determine where and why damage and destruction took place within the context of the magnitude of an earthquake, the type of motion it originated (shaking, jarring, rolling), its duration, the area it affected, and the geologic properties of rocks underlying structures' foundations. Hazard assessment teams also evaluate other factors that contributed to additional damage such as ruptured gas lines that feed fires and ruptured water lines that inhibit fire control. The engineers establish how construction can be improved in the future in terms of construction techniques and materials to prevent the types of collapses and utility failures they investigated.

Municipalities revise building codes accordingly to direct reconstruction and future building projects. Where possible, structures that withstood an earthquake with minor or no visible damage should be retrofitted to improve their resistance to the next "big one." With each event, we gain more data on how to better construct earthquake-resistant structures and alter building codes to more stringent specifications. In theory, this adaptationto an irregularly recurring global event is good, but in practice it is most applicable to nations with the economic resources for reconstruction according to revised building codes and where there is no corruption to allow a bypass of the code. The same can be stated for retrofitting to give more resistance to earthquakes to existing structures. Many developed nations and nations rich in commodity exports (e.g., oil) have a moral obligation to donate funds, material, and expertise to help citizens in economically disadvantaged nations recover from a destructive earthquake. Some commodity-rich and economically sound nations do not do so directly, whereas others, big and small, rally to help disaster victims. For example, immediately after megatyphoon Haiyan devastated many regions in the central Philippines in 2013, Israel sent 250 medical doctors and nurses and field hospitals to help Philippine citizens recover from the impacts of the typhoon.

9.3.2 Volcanoes

As discussed in an earlier chapter, volcanoes are predictable in terms of becoming active by emitting wisps of smoke, bulging on a slope, warming of the soil or nearby pond or lake waters, emitting increasing concentrations of gases, and showing increased low-frequency seismicity. However, this activity does not always result in an eruption. A marked increase in measurements and observations, especially the low-frequency seismic activity, suggests that an eruption is imminent. Adaptation to living and working on or near a volcano means investing in equipment to monitor volcanic activity and listening to alerts from scientists monitoring its activity and being ready to evacuate by gathering important papers and precious mementos and prepared to load into transportation for evacuation to safe locations. Governments adapt by charging geologists to map out areas considered as high-, moderate-, and low-hazard zones in the volcano environs. Geologists do this by studying rocks deposited from past eruptions and assessments of the topography. Municipalities then pass zoning regulations applicable to the hazard level.

9.3.3 Floods

Governments have adapted to repeated periodic flooding in areas by creating flood control systems described in Chap. 4. Dams hold water during times of heavy and/or extended rainfall and release any overflow into channels that move water away

from urban or rural population centers. Levees increase the volume of water that can move through a channel, thereby keeping it from spreading into populated areas and cultivated farmland. For smaller waterways that flow through cities, municipalities may invest in deepening, widening, and straightening channels as well as erecting walls so that more water can flow through the area more rapidly without coming out of a channel. Governments define zones on flood plains according to a recurrence interval of damaging floods (e.g., 100 years) as being off limits for residential and factory/plant construction. As much as we plan to adjust to living in an area prone to flooding, there is always the possibility of a megaevent that can overcome in situ control systems. Therefore, as described Chap. 4, governments adapt to this possibility by installing flood prediction equipment in drainage basins to provide warning to those at risk from rising and sometimes raging waters. The warning gives people time to gather important documents and personal treasures and evacuate to safe areas. The apparent increase in the frequency and magnitude of storms and resulting flooding in recent years is thought by many weather scientists to be related to global warming and the increased amount of moisture in the atmosphere from warmer oceans that gathers in clouds and precipitates during storms. This will be discussed further in this chapter.

9.3.4 Extreme Weather Conditions

Adaptation to extreme weather events such as an extended period of drought, heat waves, and frigid weather means preparation to wait them out. Some municipalities adapt to repeated, sometimes seasonal, times of short-term drought by storing a 3–6 month water supply in surface or underground reservoirs during periods of normal precipitation that can be tapped (conservatively) as needed. Others may plan to move water via pipes or water tankers from where it is plentiful to where drought conditions exist. Otherwise, to survive, people move as best they can to where they have access to water. In instances of years long drought, crops and livestock and other life forms may be lost. Heat waves can kill. Adaptation to heat wave conditions means that water has to be available to people to avoid dehydration. Where possible, homes should have air-conditioning or fans to keep people comfortable and municipalities should have cooling centers to which people can go. Personnel should check on senior citizens and escort them to cooling centers if necessary. Clearly, economically advantaged nations have the resources to give support to citizens during natural hazards such as these. These nations, international organizations, and NGOs have a moral obligation to help economically disadvantaged nations as is possible when hazard conditions such as these threaten populations.

The most extreme of weather conditions that can injure and kill people and destroy housing and infrastructure are tropical storms that evolve into violent hurricanes (typhoons, monsoons) by increasing wind speeds and sucking up moisture (water) as they track across oceans toward land. When these storms make landfall, they drive storm surges that can wreak havoc onshore communities, and as

they move inland precipitate heavy rains that cause life-threatening and destructive flooding. These violent storms are destructive to coastal populations and island nations and have regional reach inland as they move along paths until they finally spend their energy or move out to sea. On November 8, 2013, the typhoon named Haiyan, the strongest recorded typhoon ever to make landfall smashed into the central Philippines killing more than 2,600 people, injuring about 12,500, and displacing almost 600,000 people. There was a 4-m (~13 ft) storm surge driven by winds measured at over 312 km/h (195 mi/h) with gusts reaching 380 km/h (235 mi/h). The typhoon flattened the city of Tacloban that was home to 200,000 residents, and there was major flooding inland. The weather alerts led to a government call for evacuation away from the predicted path of the storm, and about 1 million people followed the evacuation warning, surely saving many lives. Access to aid typhoon-ravaged areas was difficult, and there were shortages of water, food, and medical care for many evacuees for several days. The Philippine central government and local officials were not prepared to deal with a storm of this magnitude but help started arriving from many nations worldwide. There was a post-event concern of attending to sanitation needs of survivors to prevent outbreaks of diseases such as cholera, typhoid fever, hepatitis, and dysentery. If the Philippine government had adapted by adopting better policies with respect to response to high-category typhoons in addition to the call for evacuation, the impact of Haiyan would have been ameliorated. One would hope that this deficiency would be dealt with to limit the effects of future like disasters.

Evacuation to prevent injury and death in coastal zones that could be struck by high winds, heavy sustained rains, and storm surges is dependent on weather bureau forecasts and warnings from police, firefighters, or other government-authorized personnel. Homeowners adapt to hurricanes by securing roofing with additional nails or special fasteners as a retrofit precaution and by boarding up windows on structures before an incoming storm hits. Governments have adapted to the onslaught of violent high-energy storms by constructing seawalls of varying designs and heights to protect population centers by damping the force of storm surges. In China, for example, a seawall 6.72 m (~22 ft) in height and that has been heightened in the past protects Shanghai from the full damaging effects of high-category typhoons. As a result of rising sea level, the Shanghai seawall and other that protect coastal cities from being flooded by surges from high-energy tropical storms will have to be heightened to afford a greater degree of protection to people and property.

9.3.5 Wildfires

Wildfires can be a natural hazard when ignited by a lightening strike. However, most wildfires are started by human carelessness such as tossing a lit cigarette on a forest floor or failing to completely extinguish a campfire, or by arsonists. One may adapt to living in an area with a history of wildfires in two ways, neither of which is

practical or promises 100 % protection. First would be to clear an area of vegetation in a 30-m (100 ft) swath around a dwelling or site for building. Second would be to build with nonflammable materials so that embers propelled during a wildfire could not ignite a structure. Adaptation to the advance of a wildfire would be to heed warnings to evacuate carrying a prepared case with important documents and other items of personal value. To delay evacuation by going back to retrieve something from then home can be fatal as it was for two people in a recent (June, 2013) wildfire that destroyed almost 500 homes in Colorado Springs, Colorado, USA.

9.3.6 Preparedness Against Natural Hazards

When there is a hazard event coming that calls for evacuation, responsible and often economically advantaged governments have adapted to the threat by designating evacuation routes, by providing transportation for people who need it, by having evacuation centers stocked with water and food, cots and blankets, basic medical supplies and medical personnel, and by having phone service available for people that need it. In the case of a primary or triggered hazard that happens with little or no warning (e.g., an earthquake, a tsunami, a volcanic mud flow), search and rescue teams should be ready to move in soon after dangerous conditions ease and they can move with safety. There should be medical attention to treat injured survivors, and stations set up as soon as possible to provide water, food, and other essentials available to those that survived with little or no physical hurt. These first steps at adaptation are the keys to survival. Recovery after a shock phase can be long and drawn out, depending in grand part on a nation's social and economic resources and physical and economic assistance from other nations, international institutions, and NGOs.

9.4 Adaptation to the Effects of Global Warming/Climate Change on Our Earth's Inhabitants

9.4.1 Cause of Global Warming

Global warming is a fact attested to by an overwhelming majority of the scientific community and unwaveringly supported by a February 2014 joint publication of the US National Academy of Sciences and The Royal Academy in the UK on the causes and evidence for global warming [1]. As noted in earlier chapters, during the past century, measurements show that the earth has warmed by $\sim$0.8 °C ($\sim$1.44 °F). Global warming is an ongoing process that is attributed in grand part to a slow but continuous and increasing buildup of greenhouse gases in the atmosphere. The greenhouse gas most associated with global warming is carbon dioxide

(CO_2). A plot of the increase of CO_2 content in the atmosphere with time against the increase in global temperature shows an excellent correlation of one with the other. Additional lesser contributors include methane (CH_4), nitrous oxide (NO_2), and chlorofluorocarbons (CFCs). With the beginning of the industrial revolution and the increased use of coal as the principal energy source, the content of CO_2 in the atmosphere was 280 parts per million (0.028 %). The combustion of coal and later oil (petroleum) and natural gas emits CO_2 to the atmosphere. Initially, and for many years thereafter, the added greenhouse gases were taken up by vegetation for photosynthesis and was also absorbed by the oceans and other water bodies. This kept the atmosphere CO_2 close to the 280 ppm pre-industrial level. However, with increased industrialization, the need for electrical power, and the use of internal combustion engines, the amount of CO_2 generated was greater than what could be absorbed by nature and the content of CO_2 in the atmosphere increased. During June 2013, its concentration reached more than 398 ppm, an increase of over 40 % over the pre-industrial concentration (Scripps Institute of Oceanography Mauna Loa measurement). The increasing CO_2 content, other greenhouse gases, aerosols, and particles acted as a media that admitted sunlight (heat energy) to the earth's surface but did not let all of the heat escape back into the atmosphere. This abets global warming. In the past two to three decades, the rush to industrialization in developing countries (e.g., China, India, and Brazil) and their growing power needs and vehicular use has thwarted the implementation of international agreements to reduce emissions from coal-fired power plants, other industrial and manufacturing operations, and the transportation sector.

9.4.2 Effects of Global Warming

9.4.2.1 Rising Sea Level: Adaptation/Mitigation

A direct consequence of global warming is sea level rise (SLR) caused by the progressive melting of icecaps and ice sheets in Greenland, the Arctic, and Antarctica, and of mountain glaciers in the Himalayas, the Alps, the Rocky Mountains, and the Andes. The ~20-cm (~8 in) sea level rise during the past century may see a rise of another ~50 cm (~20 in)–1 m (~39 in) during this twenty-first century. One-third of the rise would be from the expansion of warmer sea water, one-third from icecap and ice sheet melt, and one-third from mountain glacier melt [2]. In 2012, other researchers used computer models on existing data and proposed that 50 % of sea level rise between 1903 and 2007 was from glacial melt [3]. Following the same line of investigation, other scientists studied satellite data and ground measurements from Alaska, the Canadian Arctic, Greenland, the southern Andes, the Himalayas, and other high mountains of Asia and estimated that glacier contributions to sea level rise from 2003 to 2009 was 29 % and together with ice sheet melt explained 60 % of SLR [4]. A publication in 2012 estimated that ocean thermal expansion 0–300 m deep and 300–700 m deep contributed up to 35 % to

sea level rise [5]. These latter two estimations are in line with the IPCC prediction for melting ice and ocean thermal expansion contribution to the estimated rise of sea level by the end of the century [2]. With a rise in sea level, marine waters encroach on land. As the rise continues, possibly at an increasing rate, it threatens habitation in lowlying islands, coastal villages and farmland in lowlying zones, and heavily populated cities worldwide settled on inshore terrain close to sea level (e.g., Bangkok, Ho Chi Minh City, Jakarta, Manila, Miami, New York, Boston, Buenos Aires, London, Rotterdam).

Rising sea level and warming of ocean waters have other ramifications that affect coastal communities as well as inland areas. As explained in Chap. 7, the warmer surface water releases more water vapor with heat energy into the atmosphere. When the water vapor molecules condense in clouds, heat energy is released. This energy gives more force to tropical storms as they form, track to shore, and move inland, or storms that move close to and along a coast. These storms may transition to hurricanes (typhoons, monsoons) with the violent winds that cause destruction, and heavy rainfall that triggers flooding if they move onto land. We recognize that rising sea level means that tropical storms that impact a coast with storm surges have a farther reach inland with their destructive energy that is more pronounced when the surge occurs at high tide. The surges also saturate farmland they reach with salt water that harms crops. They also carry salt water into fresh water marshes and ponds, thus disrupting ecosystems there. The increase in the number of these extreme weather events and the increase in violence and destruction they wreak on land compared with like weather events in the recent past (e.g., during the past 30 years) strongly suggest that they are fueled to a significant degree by global warming.

There are two possibilities for adapting to the effects of rising sea level on coastal urban centers, one impractical, the other very costly but doable. The impractical adaptation possibility is to move at-risk population centers inland, out of the reach of the destructive tropical storms. This does not lessen the threat of flooding. The move is possible in some cases where land is available, but such a move is not economically feasible. One practical but costly adaptation to mitigate encroachment from sea level rise and the effects of tropical storm surges is to surround cities at risk within place seawalls 2–3 m higher than recorded high tides or higher depending on historical records and contemporary published data. The walls can have a concave configuration so that surging waves lose energy when their lower parts hit and are curled back on themselves damping some wave energy or there can be a different configuration best for the site(s) to be protected. Similarly, gates buried at strategic locations where there is ship access to consider can be built to be hydraulically driven so that they can rise from a near shore seabed site to mitigate the effects of storm surges. Both techniques have been used at different global locations.

9.4.2.2 Food Security: Adaptation to Climate Change by Land-Based Agriculture

We have read that climate change affects land-based agricultural production, both for crops and animal husbandry. The warming climate at higher mid-hemispheric latitudes and at higher altitudes does not favor the growth and normal yield and/or quality of many crops. Depending upon the degree of climate change and the linked change(s) that may follow it, farmers can adapt in several ways to maintain or increase crop yield and nutrition value. For example, when warming starts diminishing the productivity of a traditional crop, farmers can sow crops that are known to grow well in warmer temperature and give a satisfactory economic benefit. However, new groups of weeds, pests, and diseases will migrate to the warmer growth environment and will have to be dealt with in order to protect the new crops.

Where the effect of global warming reduces water supply for rain-fed agriculture, for crops irrigated with surface waters, and for groundwater-irrigated crops when aquifer recharge does not balances discharge, agriculturalists can adapt in two ways. First is the use of a more efficient irrigation method that delivers water directly to a growing plant (e.g., drip or focused irrigation). This minimizes runoff and loss to evaporation. Second and similar to what was mentioned earlier is to sow a crop that needs less water to thrive and that delivers a good yield, good-quality product.

Another result of global warming for some farmlands is a longer growing season. In this situation, growers can adapt by planting earlier and have the possibility of double cropping. They can also grow a cultivar that is later maturing and that gives a product that brings a good market price. However, switching to new crops in a warmer growth environment means that there will be an invasion of a new set of weeds, pests, and diseases to ward off.

In any efficient operation, and as emphasized in earlier chapters, farmers adjust to a changing growth environment for a given cultivar by applying the optimum amounts of fertilizer and other agricultural chemicals as might be needed that nurture and protect it most effectively. This reduces agricultural costs and lessens runoff of these chemicals to ecosystems where they can be harmful.

Global warming can bring on abnormal weather extremes that affect agricultural productivity. In these cases, farmers have to plan ahead based on recent history of these conditions in their regions. Drought, heat waves, and long-term rain or heavy rain in a short time present problems for both cultivars and food animals. Periods of less than average precipitation may last months or years. Depending on the amount of the deficit precipitation, adaptation can include storing water in reservoirs and cisterns during times of rainfall to be tapped during a drought to sustain food animals and crops during a short-term, not too severe drought. There is also the option of trucking in water to sustain livestock. Long-term droughts when precipitation deficits are high take their toll on plants and animals to the detriment of agriculture in a region especially when accompanied by heat waves. They have caused recent disasters for crops and food animals on all continents less Antarctica.

Farmers either wait out the "bad times," change the type of cropping they do, the livestock they tend to, or change careers.

The adaptation from crops that have been grown successfully before the effects of global warming reduced yields and quality of a harvest, to those "same" crops that can grow successfully under the advancing warming changes just described generally means that hybridized species have to be developed and used as warming increases at a location and slowly tracks to higher latitudes and higher altitudes. Thus, growers turn to plants that are created by hybridization as described in Chap. 3: traditional methods and marker-assisted selection methods within the same species, and genetically engineered (-modified, -manipulated) methods using different species. Hybridization is a slow process, sped up markedly by genetic engineering, a method that yields foodstuff not accepted by the European Union and many nations outside the Union, especially in Africa. Bred species are developed to carry one or more characteristics that favor crop resilience against the effects of climate change. These include resistance to disease, weeds, and pests, and tolerant of drought (water stress), heat, short-term inundation, and short-term saline exposure (see Chap. 3). Hybrids have also been developed to give higher yields and more nutritious crops. Thus far, research has been focused mainly on improving seed for world staples such as rice, maize (corn), wheat, sorghum, and soybean.

There have been great successes where hybrid crops were agriculturalists' adaptation so that the possibility exists that we can feed the earth's growing populations and reduce chronic malnutrition. When this is coupled with the opening of additional arable acreage and the use of improved farming methods for seeding, watering, and harvesting, global food security can be strengthened for the existing world population and the future generations on earth. However, this will require economic and technical input by developed nations and international groups. Without basic sustenance, people will have less resistance to diseases and there may be local or regional population crashes if diseases evolve into epidemics or pandemics that invade susceptible populations.

9.4.2.3 Adaptation of Marine Fisheries and Aquaculture to Climate Change

Warming of the open ocean water, enclosed aquaculture operations in ocean waters and on land water bodies has affected marine fisheries and marine and estuarine aquaculture that grow food fish and shellfish, and lakes that sustain fisheries. In marine fisheries worldwide (e.g., in the north Atlantic, off the coast of Peru, off the coast of the Philippines), some food fish or fish captured for other purposes (e.g., to use in pet food, to use to make fertilizer) have migrated to cooler water in ecosystems with conditions conducive to their spawning and growth. In some cases, predators follow fish they prey upon that have migrated to cooler waters, but in other cases they find new prey to sustain them. In other situations, they may become prey for larger fish in an ecosystem. Fishing fleets adapt by following the fish they hunt into cooler waters where ideally they capture the hunted species in quantities

allotted them by national and international fishery governing body regulations. If the quota system is followed, this will allow recovery of fish populations and sustainable harvesting.

Aquaculture operations that provide important supplies of food fish worldwide can adapt to warming waters by raising food fish or shellfish that will grow and multiply under the changed range of day/night temperature conditions if the fish they are farming cannot survive in the warmer waters. Aquaculturalists also have the option to move their facilities to cooler-temperature waters, but the economic feasibility of doing this has to be evaluated by a benefit to cost analysis. This analysis has to be for the time frame during which the cooler-ecosystem waters are estimated to remain stable within the framework of a time range against global warming/climate change. Another adaptation is that food fish currently being raised can be genetically engineered to be resistant to a warmer growth environment without changing their nutrition yield, growth rate, and ability to reproduce.

9.5 Adaptation to the Threat or Onset of Endemic, Epidemic, and Pandemic Disease

There are diseases that are global threats, others that put regions at risk, and yet others that menace smaller political divisions. Humans adapt to the threat of sickness in a population or a sickness itself in several ways. Scientists develop methods to eradicate a virus or bacterium health threat, or a chemical/radioactivity threat. Failing this, health professionals act to control a disease, to slow or minimize its transmission, and to apply approved therapies and support research to find therapies to treat an illness if one is transmitted. The following discussion draws strongly on the 2013 disease fact sheets put out by the World Health Organization.

9.5.1 Adapting to Global Health Threats

Vaccines provide a main line of defense against many diseases. Smallpox has been eradicated on earth by vaccination. Polio has all but been eradicated globally except for a few pockets of the disease in Pakistan, Afghanistan, and Nigeria where, in some cases, religious fundamentalists have beaten and killed health workers tasked with giving the vaccine to children, and in other cases where parents have been warned by the zealots against allowing their children to be vaccinated. Recently, 81 polio cases were diagnosed mainly in Somalia but also in Kenya. This is attributed to the fact that by 2013, 500,000 children in Somalia have not received the vaccine and are at risk from this highly contagious disease. It is also attributed to cross-border migration of infected persons into Kenya. Both governments are stepping up their vaccination programs. There were 59 cases of polio diagnosed in the rest of the world in 2012.

Measles is a global disease that can be prevented by a vaccine that is safe and cost-effective. Measles may soon reach the near-eradication stage. In 1980 and subsequent years, 2.6 million people, mainly children under 5 years of age, died from measles. Since 2000, 1 billion children were vaccinated, 225 million in 2011. By 2011, 84 % of the world's children received the measles vaccine, up from 72 % in 2000. From 2000 to 2011, deaths from measles dropped to 71 %, from 548,000 to 158,000. When the vaccination rate reaches 95 %, mainly in low-income countries, the world will have brought another disease close to elimination [6].

Seasonal influenza is a global viral illness that afflicts 3–5 million people. The sickness kills 250,000–500,000 people with severe symptoms annually. Transmission of the virus takes place when an infected individual coughs or sneezes without covering his/her mouth and releases droplets that can be inhaled by someone up to a meter away. Transmission can also be from hands carrying the virus. Seasonal influenza affects all age groups, but children less than 2 years old, people over 65, and those with complicating medical problems are most at risk. Influenza is a disease to be controlled. The principal control is by safe and effective vaccines that can prevent 70–90 % of influenza cases in healthy adults. Secondary controls are obvious for infected persons: cover the mouth when sneezing or coughing, and wash the hands frequently. The influenza vaccine is taken once annually. Because strains of the influenza virus change from year to year, adaptation is needed. The adaptation is via a vaccine that is prepared with 3 or 4 strains that scientists determine will be most common during a coming season [7].

Other types of influenza and respiratory illnesses have the potential to cause an epidemic or pandemic. They include avian flu and its strains and swine flu if the strains develop the ability for person-to-person transmission after infection, and SARS (severe acute respiratory syndrome) and Middle East respiratory syndrome (MERS) because there is human-to-human transmission of the sicknesses. To the present, the outbreaks of the animal influenza diseases have been contained by quarantining infected people during treatment and by culling flocks and herds, or if available, vaccination of healthy animals. The latter two respiratory illnesses are caused by the coronavirus, and infected people have been in isolation wards. For SARS, an illness that broke out in 2003 and spread to 24 countries, isolation of victims and treatment with antiviral drugs and steroids stopped the disease during 2004. MERS is a recent (2012/2013) illness that has been confined to Jordan, Saudi Arabia, Qatar, and the United Arab Emirates. The MERS virus has been found in camels. Infected persons are quarantined in hospitals, but an effective drug treatment is still being sought to complement the normal hospital care-afforded patients.

HIV/AIDS is a global epidemic that killed 25 million people in three decades since 1981. Worldwide, in 2011, there were 34 million people with HIV, mainly (33 million or 97 %) in sub-Saharan Africa and South/Southeast Asia. The illness is caused by the exchange of body fluids (semen, vaginal excretions, blood, breast milk) from an infected individual with an uninfected person. More than 50 % of the cases of HIV are from heterosexual activity. There is no vaccine against HIV/AIDS, no cure for it, but there is a cocktail of medicines (antiretroviral treatment) that control viral replication and allow an infected person's immune system to

strengthen. This keeps the illness at bay and afflicted people in general good health and productive in their communities. In 2012, only 9.7 million (less than 30 %) of those with HIV in low and middle economies received the antiretroviral treatment. This is changing as more HIV carriers have access to antiretroviral therapy and there are more donations from economically advantaged countries to support HIV stabilization and reduction programs. The number of new cases of HIV is not exploding because more than 50 % of those infected are following protocols that reduce the transmission of the disease.

The prevention of transmission methods include access to male and female condoms, blood screening before transfusions, and needle and syringe exchange programs for sterile injections by drug users. HIV testing and education programs and HIV treatment help prevent transmission because individuals in continuous treatment have a very low probability of passing on the disease. Male circumcision reduces the infection in men by about 60 %. There is still much progress to be made because there were 2.5 million new cases of HIV in 2011, with 1.8 million of that total in sub-Saharan Africa. The HIV/AIDS is a global sickness that is slowly coming under control because of generous donations from governments and foundations in developed countries added to what low- and middle-income countries themselves provide to lower the prevalence and incidence of HIV in their populations [8].

Tuberculosis (TB) infected 8.7 million people globally in 2011, killing 1.4 million persons. It is a bacterial disease that spreads among people when infected individuals cough, sneeze, or spit, releasing bacteria into the air where they can be inhaled by others a meter away. Although TB occurs worldwide, developing countries carry the largest burden of cases and deaths (95 %). The bulk of new cases are regional in Asia (60 %) with sub-Saharan Africa reporting a large share as well with 2,600 new cases per million inhabitants. There is no vaccination for TB, but the disease can be treated and cured. The treatment is a half-year course of four antimicrobial drugs that must be taken without fail and thus requires continual supervision by healthcare personnel. More than 51 million people have been treated and cured of TB since 1995 and perhaps 20 million lives saved by following the WHO Stop TB Strategy protocols including securing adequate, sustained financing, ensuring early reliable detection and diagnosis, and providing approved treatment with a secure effective drug supply. The number of people infected with TB is declining, and from 1990 to 2011, the TB death rate dropped more than 40 %. The success in dealing with TB is muted somewhat because a strain of the bacterium that causes TB has evolved to be multidrug resistant (MDR-TB). In 2011, 310,000 cases of this variant were reported (of the 8.7 million cases worldwide), mainly from India, China, and the Russian Federation. These are treated with, but do not always respond to, the most effective anti-TB drugs. Research into new drugs to deal with this problem is ongoing [9]. There is the question of whether people visiting or immigrating from these countries should be screened before a host country issues them entry visas.

9.5.2 Adapting to Regional Disease Outbreaks

Regional illnesses threaten the health of 100s of millions of people mainly in tropical and subtropical areas and often affecting children. One of these, the guinea worm disease, is trending toward elimination, if not eradication. This is a parasitic disease caused when people swallow water contaminated with infected water fleas (microscopic copepods) carrying worm larva. The worms release, penetrate the intestines, and move through the body migrating under the skin until they emerge causing swelling and blistering. People infected with guinea worm disease cannot contribute to their communities for months. During the mid-1980s, there were 2.5 million cases mainly in 16 African nations. But attention to where the sources were so that they could be avoided and treated, and assistance in generating clean water, were adaptations that brought the number of cases down to less than 10,000 in 2007. The number of cases continued to decline and was reduced to 542 in 2012 in four African countries: South Sudan, Chad, Ethiopia, and Mali. There is no vaccine against guinea worm disease. Health officials adapt to counter this sickness in several ways. As noted above, access to clean drinking water is the best way to prevent infection. The prevention or transmission of the worms from infected individuals to healthy persons by proper treatment and hygiene and the use of the larvacide *temephos* to eliminate the parasite-infected water flea vector and other prevention protocols are important in the control and effort to eliminate/eradicate the disease [10]. The (Jimmy) Carter Institute, Atlanta, Georgia, USA, has been a principle force since 1986 in the fight to rid the world of guinea worm disease.

In tropical and subtropical regions, there are three mosquito-vectored diseases that put millions of people at risk: yellow fever, malaria, and dengue fever. Yellow fever is an endemic viral disease in tropical regions of Africa and Latin America with 200,000 cases reported annually that cause 30,000 deaths. There is no set treatment for afflicted people, but there is an adaptive preventive measure. A vaccine against yellow fever is available that is safe, affordable, and that gives lifelong immunity to the disease with one dose after 7–10 days for 95 % of the people vaccinated. When there is the onset of a yellow fever outbreak where the population lacks vaccination protection, mosquito control is an essential first step in adaptation to prevent or slowdown transmission of the yellow fever virus. Spraying insecticides to eliminate breeding sites and kill adult mosquitos is the control used during epidemics to make time for vaccination campaigns in a population and for immunity to take hold. There are limitations to the application of the yellow fever vaccine. First is that babies less than 9 months of age should not be vaccinated or, during an epidemic babies less than 6–9 months of age should not receive the vaccine. Second, pregnant women should not be vaccinated except when there is an outbreak of the disease. Third, people with a strong allergy to egg protein or those with a marked immunodeficiency or with a thymus problem should not receive the vaccine [11].

Malaria is a parasitic disease caused by the bite of an infected mosquito. There is no vaccine against malaria, but one is undergoing a clinical trial in seven African

nations with results expected in 2014. A use or no use decision as a control method for malaria will be made in 2015. Promising results from an early-stage clinical trial of an unconventional vaccine prepared with live, weakened sporozoites of the malaria parasite were published in 2013. Plasmodium falciparum was given to healthy 18–45 year-old volunteers intravenously. The volunteers were grouped to receive 2–6 doses and subsequently exposed to bite by five mosquitoes carrying the parasite. None of the six that received five doses were infected with malaria. Three of the 12 that received four doses became infected, whereas 16 of the 17 that received lower doses became infected. Of 12 that received no vaccine, 11 became infected. Those that became infected were treated with malarial drugs and cured. Clearly, higher dosages give protection against infection by malaria [12]. More research and extensive clinical trials are necessary to determine how children respond to the vaccine with adjusted dosages and whether the results from early-stage trial are reproducible in larger volunteer populations. If the results of additional clinical trials go well, the hurdle of producing enough vaccine and adapting it to injection has to be faced.

Forty percent of the deaths from malaria are of African children in the Democratic Republic of Congo and Nigeria. In addition to sub-Saharan Africa, populations in Asia (especially India and the Greater Mekong region) and Latin America suffer from the disease. The effort to deal with the disease that is preventable and curable now centers on control and treatment to reduce the number of cases. In 2010, the WHO reported that there were 219 million cases and 660,000 deaths (with an uncertainty range of 490,000–836,000). In a 2012 report, researchers suggested that the number of deaths was understated and that their computer model gave a figure for 2010 almost double, 1,238,000 deaths (95 % uncertainty interval of 929,000–1,685,000) [13]. The WHO stood by its figure stating that much of the data in the cited study were based on verbal testimony of how people had died, not on laboratory diagnosis of samples. Either figure represents too many deaths from the disease and have to be reduced. Mosquito control is the adaptation that can reduce the transmission of the disease greatly. This includes personal protection by use of proper clothing and/or the application of mosquito repellent, the use of long-lasting insecticidal (pyrethroids treated) nets to kill mosquitos and prevent nighttime bites, and indoor residual spraying (remains effective for months). Those people infected can be treated with oral *artemisinin* monotherapy followed by a second drug. Failure to complete the treatment as prescribed leaves parasites in a person's blood. No other antimalarial treatment is available so that parasite resistance could become a serious problem. For visitors to a malaria region, antimalarial drugs taken before, during, and after a trip can protect them from the disease. Many countries in tropical and subtropical areas have used the above-cited strategies and others to work toward the elimination of malaria. Malaria eradication is the goal of the WHO [14].

Dengue fever is a female mosquito-borne virus that infects people with an influenza-like disease in tropical and subtropical regions worldwide. The disease can kill if it evolves to severe dengue. It is endemic in Latin America and Asia where most cases now occur. Since the 1970s, the sickness has spread to more than

100 countries putting about 35 % of the world's 2013 population (2.5 billion people) at risk. Dengue fever is especially endemic to urban/semi-urban environments. Humans are the main carrier of the virus. After a mosquito bites an infected person, each subsequent bite by the infected mosquito creates another carrier. A mosquito can bite many people each time it feeds. In the Americas alone, there were 1.6 billion cases of dengue fever reported in 2010 with 49,000 being severe dengue. There is no vaccination against dengue fever, but research continues to develop one. The main treatment for afflicted persons is to keep them hydrated. Adaptation to deal with slowing or stopping the spread of dengue fever involves three main tracks in addition to spraying insecticide to kill mosquitos. The best control method to prevent the transmission of the virus is to deprive mosquitos of sites with shallow, standing water where they can lay eggs and multiply. Control can be improved if communities cover and clean water storage containers regularly, and use proven insecticides on them as necessary. Finally, individual protection such as the use of mosquito repellants and insecticide-impregnated bed nets can help reduce the incidence of dengue fever as it has with malaria [15]. Although controls are known, they are not always applied because of economics and other factors that prevent access to protection methods. The result is that the number of cases of dengue fever reported continues to grow globally. As populations increase in urban locations, the incidence of dengue fever can be expected to increase as well unless strict controls are enforced until a safe and cost-effective vaccine is developed. A positive aspect of the dengue fever problem is that recovery from one serotype of the virus gives immunity for life. However, there are four serotypes of the infectious virus so that recovery from one leaves a person susceptible to the others [15].

Chagas is another regional disease. It infects 7–8 million people annually, mostly in 21 Latin American countries. It is a parasitic illness that evolves after the bite of a blood-feeding *triatomine* bug, often on the face, where it defecates close by leaving parasite-bearing feces. Parasites access the body when the feces are inadvertently smeared into the bite, the eyes, the mouth, or any skin lesion. The parasites circulate in the blood expressing their presence as a purplish swelling of one eyelid or as a skin lesion. There are several other symptoms as well in this acute stage of the illness, but these may be absent or mild. If diagnosed early during this stage, Chagas disease is treatable. The parasite is killed with the medicines *benznodazole* and *nifurtimox* taken for 2 months. There are limitations as to who can take these medicines (e.g., not by pregnant women or people with kidney or liver problems). The untreated sickness can cause cardiac alterations and digestive problems that show up 20–40 years after an untreated infection. Chagas disease can be spread by blood transfusion and by organ transplant, making blood screening for the parasite essential before a procedure. It can also pass to a fetus from an infected woman. There is no vaccination against the illness so that control of the vector (*Triatomine* sp.) is necessary. The controls adapted by many municipalities include insecticide spraying inside a home, the use of treated bed nets, and hygiene practices that protect food, its preparation, and its storage before eating it [16]. The sickness may recur if control practices become lax. Chagas disease is spreading as populations emigrate from Latin America to northern countries. Blood screening of

visitors or immigrants from the countries where Chagas is endemic may be necessary, and treatment followed by an infected individual before a host country issues an entrance visa. This would prevent the ingress and possible spread of Chagas.

9.5.3 Adaptation to Localized (National, City) Health Threats

Outbreaks of diseases in town and cities is most often caused by bacterium-contaminated water or food and poor sanitation. Sicknesses such as cholera, typhoid, and various other diarrhea types are examples of such diseases. They are all highly infectious if good hygiene practices are not followed. These diseases are endemic in many countries where populations do not have access to safe water and adequate sanitation. There are vaccinations for some of these sicknesses that may require more than one dose, but they may not be completely effective or long lasting and require revaccination at times specified by medical personnel (e.g., after 2–5 years). Otherwise, infected persons can be treated with medicines such as oral rehydration pills or antibiotics. Adaptation for prevention is easier called for than realistically available: washing hands with soap and clean water after visiting the toilet, and as noted above, access to safe water and good sanitation. Given the millions of people infected by these bacterial diseases and the hundreds of thousand that die from them annually, generally in economically disadvantages countries, there should be an expanding global priority to eliminate the disease-causing conditions, and preparedness to combat an outbreak when it is reported.

9.5.4 Planning Ahead to Stem Future Health Threats

There are important factors to consider when adopting plans to halt or meliorate the effects of health threats to people in the near and extended future. One is the climate change-driven spread of tropical and subtropical diseases discussed earlier to newly warmer and moister higher-latitude and higher-altitude zones. Another is the growth of populations mainly in tropical and subtropical regions in Africa, Asia, and Latin America. Together with this latter factor are the increasing populations and population densities in urban centers especially in the regions just cited. An additional factor to consider is whether there is accessibility to populations by healthcare workers or by people to healthcare clinics or hospitals, well-staffed and well-stocked with necessary pharmaceuticals.

Certainly, future planning has to include funding to support research to develop vaccines for diseases that do not have vaccination as an option against an illness (e.g., malaria, dengue fever) . In addition, improvement of vaccines that are available but that are not completely effective in terms of protection or the length of time they are effective should be a priority in pharmaceutical and biotechnology laboratories.

Scientists presented a fine review of the status of vaccine research from the design and development of vaccines to discussion of vaccines and infectious diseases (e.g., HIV, malaria, tuberculosis, pneumococcal disease, and influenza) [17]. They also discuss vaccines against enteric infections and viral diseases of livestock as well as vaccines against non-infectious diseases (e.g., cancer) and against chronic non-infectious diseases. Continued and repeated education classes on how to prevent the transmission of diseases and free supplies of materials that work to this end (e.g., insecticide-treated bed netting, male and female condoms) are essential to reducing the prevalence and incidence of diseases as are safe water and uncontaminated food. As new medicines or combinations of medicines are developed, tested, and found to be effective in controlling diseases, they become part of the protocol for either curing disease or controlling disease to reduce transmission while allowing persons to carry on with their lives. In these times of easy and rapid migration, one wonders whether screening of visitors or immigrants for diseases known to be endemic or active in the countries or regions from which they come should be required so as to prevent a carrier from infecting others and spreading a disease (e.g., Chagas disease, cholera, tuberculosis). This was done at airports during the SARS scare for people leaving or entering a country (e.g., China) and likely limited the transmission of the SARS virus and spread of the disease.

Preparedness for a disease outbreak, response to an outbreak, and management of resources during and post-outbreak are the keys to adapting to health threats that could affect future generations. This means developing the capability to extend the reach of health services to regions where climate change brings warmer, moister conditions to higher-latitude and higher-altitude ecosystems that are now reached by disease vectors that have expanded into these formerly cooler and drier environments as a result of global warming. Adapting to this reality and planning ahead makes it possible to deal with and stem an incipient outbreak of disease before it is transmitted and spread to the general population. This becomes essential when there is a future disease outbreak in large, dense populations in tropical and subtropical urban centers as well as those in regions warmed and humidified by climate change to subtropical and tropical settings. Remember that urban populations worldwide, especially in Africa, Asia, and Latin America, are where much of the global population growth will take place during the next few generations. Under these conditions, diseases can spread rapidly in many ways. These include from bites of vectors, by respired droplets after an infected person coughs or sneezes, and by touching surfaces bearing viruses, bacteria, or parasites. Diseases are also spread by ingestion of contaminated water and/or tainted food, and by other methods of infection transmission. Disease transmission can be checked by rapid response teams with appropriate and sufficient supplies to treat (and perhaps places to quarantine) those in the infected population.

Lastly, it must be noted that there are many other diseases in addition to those cited previously for which prevention, treatment, and cures are research priorities in laboratories worldwide. In addition, there are addiction diseases that can trigger health problems in important segments of society. These include smoking (e.g., emphysema, lung cancer), alcoholism (e.g., cirrhosis of the liver), drugs (e.g.,

various psychological and physical ills), and overeating (obesity, diabetes, high blood pressure). Adaptation to these health threats involves public education forums through various media outlets, counseling, and sponsored groups with their individual group meeting, and programs are assisting many in breaking from an addiction to the benefit of a healthier life. Adaptation to meet the health challenges in the past, and in contemporary times has been a slow, progressive adventure with many successes but with much yet to be done. This is the planned path for the future: meet the challenges of societal health threats, resolve many, and keep researching to resolve others.

9.6 Afterword

A special IPCC report in 2012 examines in a general way adaptation to a changing climate as a risk management approach [18]. It uses pre-planning to reduce exposure and vulnerability to extreme hazard events by preparing for them beforehand, responding to their impacts on people, structures, and infrastructure, and having in place recovery systems that can act when a danger condition eases. In this way, there will be an ability of populations to cope with future risks brought on by a changing force with which a hazard impacts a community, changes in the frequency of an occurrence, and extension of the spatial reach of its destructive power. Much of this has been discussed in the chapters of the book you are reading.

An understanding of what is being done now to adapt to the various problems society faces during the second decade of the twenty-first stimulates proposals of how to adapt to them as global conditions change in the future. To this end, the World Bank commissioned a study on the effects global warming as it increased from 0.8 °C that exists on our planet now to what can be expected if the warming reached 2 °C, a change that many scientists believe we can adapt to, and then reached 4 °C as warming continues [19]. The study centered on regions with high population growth and great susceptibility to be negatively impacted by climate changes: (1) sub-Saharan Africa where food production is at risk: (2) Southeast Asia where coastal zones and productivity are at risk; and (3) South Asia where there could be extremes of water scarcity and excess. The effects of higher temperatures from global warming and climate change included what has been discussed in previous chapters of this book: heat, drought, sea level rise, coastal zones, typhoons, flooding, river runoff, water availability, ecosystem shifts, crop yields, fishing, aquaculture, livestock, health and poverty, and tourism. Projections such as those published in the World Bank study give impetus to governments, international institutions, multinational companies, private foundations, and NGOs to think now, to invest now, and to research now for adaptations that can be realized in good time and that will provide global citizenry with a good quality of life where needed.

9.7 Epilogue

In this book, we have examined existing human populations and the problems they are experiencing in the second decade of the twenty-first century and have also considered growing populations globally and additional problems future generations will experience. We have discussed strategies on how to cope with many-faceted threats to citizens. These include how to nourish those who need food and water, how to shelter people safely from natural and anthropogenic hazards, how to provide them with healthcare, education, and employment, and how to prepare them for the evolving global warming and the physical and biological dangers that ensue from climate change. Given the present global conditions with about 14 % of our earth's population suffering from malnutrition and more than 21 % not having access to safe water, our capability of nourishing a billion and a half more people by 2035 is in question. Also problematical is our capability to provide for an additional billion people 15 years later, or a total of at least 10.3 billion people by the turn of the century, that is, if we reach those population figures or have population crashes such as from pandemics that can kill scores of millions if a disease is not immediately treatable, or an unlikely but possible nuclear conflagration that could do the same. Less likely yet is an explosion of a small asteroid or comet in the atmosphere such as happened in a poorly inhabited area of Siberia in 1908. Here, an exploding mass more than 60 m in size knocked down millions of trees in an area greater than 2,000 km^2 (close to 800 mi^2) with energy thought to be 1,000 times greater than the Hiroshima atomic bomb. Clearly, such an event could kill the population of a megacity if it were to occur.

Another question is whether national governments are economically strong enough and have the will to set priorities that adopt strategies to protect citizens from natural (e.g., earthquakes) and anthropogenic (e.g., pollution) hazards as well as from extreme weather conditions that are supported by global warming (pollution of the atmosphere) but are naturally occurring. Countries can also improve social and economic conditions by investing in health care and education for their citizens in order to form a sound and knowledgeable cadre that would be attractive to investors interested in locating a development project that would provide employment. Again, this is in question given limited national economic capabilities and the increasing numbers of people to be accommodated, especially in several developing and less developed countries in Africa, Asia, Latin America, and the Middle East.

At this point, we must ask, "What is the carrying capacity of the earth?" Have we reached it at 7 billion given the billions who are today under served in developing and less developed countries? Some scientists will answer yes, whereas others believe that advances in agriculture and technology can allow population expansion although to what point is not defined. Can countries that are poisoning their environments do a turn around to save their citizens from grief? Can they exert controls on operations that create unhealthy conditions that sicken people, lessen agricultural production, and otherwise disrupt local, regional, and global

ecosystems at the expense of maintaining their GDP and increasing it? This is not the case for many nations today that do not want to acknowledge that changes tomorrow may be too late and that the future begins now. Without action now to activate programs to sustain and nurture our ecosystem earth, the future is bleak for many and bright for a few. With action now, we can strive toward an equalization in benefits for all citizens. The Intergovernmental Panel on Climate Change completed the Fifth Assessment Report April, 2014 after this book was written. "Climate Change 2014: Impacts, Adaptations, and Vulnerability." It is a comprehensive and important contribution to the challenges presented to society by climate change now and in the future and how to manage them for the good of society. The full text is online at www.ipcc.ch/report/ar5

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